ECOLOGICAL PROCESS STUDIES OF A BARRIER ISLAND-LAGOON SYSTEM, BEAUFORT SEA, ALASKA

by

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Abstract

Early in 1976, the Outer Continental Shelf Environmental Assessment Program of the National Oceanic and Atmospheric Administration conceived and funded a three-year environmental study, structured in part to test a new strategy for environmental research and impact assessment. The study focused on a coastal region of the Beaufort Sea in Alaska and combined the interdisciplinary research expertise of biologists, geologists, oceanographers, and system modelers to study certain ecosystem processes. As a strategy for impact assessment, processes to be studied were selected because they both supported organisms identified to be of special interest to society, and were judged to be directly vulnerable to predicted development activities. Innovations of the research program included a model-mediated system for eliminating low-priority research, and provision of cost-effective short cuts for studying ecosystem food webs. Research showed that (1) important species of fishes and birds eat mainly epibenthos (mysids and amphipods), (2) this epibenthos may be abundant far in excess of the needs of the fishes and birds, (3) the epibenthos is dependent on pelagic primary production for food and probably on nearshore circulation patterns for transport, (4) circulation patterns are driven by wind and landforms, and (5) coastal landforms are mostly reworked mainland remnants not nourished extensively by transport of material from elsewhere. Implications of these results to assessing impacts of development in this and other coastal systems are discussed.

Introduction

Studies commissioned by the Outer Continents'l Shelf Environmental Assessment Program (OCSEAP) in Alaska initially focused only on contaminant and biological baseline studies; studies of the sources, transport mechanisms, and effects of contaminants; and studies of environmental hazards to development. When some of OCSEAP's research planners perceived that studies of these kinds could not provide all the information necessary to assess the impacts on biota of the expected developments, they proposed a supplementary approach-- studies of ecosystem processes --to aid in the prediction of impacts.

In 1976 OCSEAP initiated a "process study" of a barrier island-lagoon system on Alaska's Beaufort Sea coast. The conception of process studies grew out of experience from the U.S. International Biological Program, in which the biome approach was successful. The study focused on barrier island-lagoon systems, partly because the barrier islands in the eastern United States had proven so sensitive to mismanagement (see DoIan et al. 1973). A significant portion of the budget of the study was spent at the outset for research planning. The management and biological research portions of the program were contracted to a private research organization; physical process studies were contracted to university specialists.

The strategy of the Barrier Island-Lagoon Process Studies Program was to clarify critical geological, oceanographic, and ecological processes operative within the area of study, to identify which of these processes were likely to be interrupted by development, and ultimately to extrapolate the research findings to places outside the study sites. The objectives were stated to be

1. To identify and analyze those components and processes that contribute significantly to the structure and productivity of the nearshore ecosystem.

2. To evolve mechanisms whereby the important components and processes can be evaluated for their reaction to man's activities.

3. To determine the feasibility of detecting and quantifying the temporal changes in important ecosystem components and processes.

Study Area

The field research was conducted in the Simpson Lagoon-Jones Islands area about 30 km west of Prudhoe Bay on Alaska's Beaufort Sea coast. The lagoon system opens to the ocean at both east and west ends, and additionally connects with the marine environment between several of the islands that separate the lagoon from the ocean. The lagoon is shallow (mostly less than 3 m), freezes to a depth of about 2 m in winter, and is clear of ice during the delayed "summer", from about mid-July to early October. During this ice-free period, waterfowl and shorebirds use the area for feeding, resting, and/or molting prior to their southward migrations. Several species of birds nest on the barrier islands. Anadromous and marine fish feed in the lagoon during the open water season. Most marine mammals are restricted to deeper waters farther offshore, although a few ringed seals use the lagoon in summer.

Methods

Study methods were of two interrelated kinds--those used to design research, and those used to conduct the research. An adaptive systems modeling approach (see Helling 1978), applied at a series of interdisciplinary workshops, was used to structure communication among research disciplines, to help formulate disciplinary objectives, and to incorporate results into a cross-disciplinary view of ecosystem processes. The modeling workshops were the core of an iterative procedure for focusing research on the agreed-upon critical issues. This focusing effort continued throughout the program, and involved a sequential series of decisions as follows:

1. A limited number of system components (species} were identified at the outset as important or "key" species--equivalent to the "red flag" species of Odum and Cooley (1976) and the "indicators" of Helling (1978). As the study progressed and provided additional data, a few changes were made in the list; the species ultimately addressed were birds (oldsquaw ducks, Clangula hyemalis; red and northern phalaropes, Phalaropus fulicarius and Lobipes lobatus) and fish (arctic char, Salvelinus alpinus; arctic and least cisco, Coregonus autumnalis and C. sardinella; arctic cod, Boreogadus saida; fourhorn sculpin, Myoxocephalus quadricornis).

2. A major emphasis of the study was to add to existing knowledge of food chain dependencies of the key species. The major pathways in the food chain of each species were documented to the

extent possible, beginning with the species itself and proceeding step by step down the chain. (This strategy of constructing food chains "from the top down" did not result in a complete ecosystem food-web description; it eliminated consideration of those nutrient cycles and energy pathways that did not strongly influence a key species.)

3. As the key species and their major food chain organisms were identified, research was iteratively structured to study the physical, chemical, and biological processes that maintained foods and habitats optimal for each key and food chain species.

Research efforts concentrated on the processes thought important to the support of key species and judged susceptible to alteration by development actions. Scientists utilized conventional observation and capture techniques (Johnson and Richardson 1981; Craig and Haldorson 1981; Griffiths and Dillinger 1981) to study the distribution in time and space of the key species of vertebrates and their prey. The food habits of the vertebrates were determined by analyzing their stomach contents; the food sources for their primary prey (a few species of epibenthos--mysids and amphipods) were evaluated by carbon-isotope analyses of their body tissues (Schell *1979).* This determined whether the food of the epibenthos was old (organic peat derived from the mainland) or new (recent marine production), and whether it came from terrestrial or marine sources.

Nearshore circulation (as it affected the transport of organic detritus nutrients, and epibenthos) was studied by deploying current meters and surface drifters, making time-synchronous measurements of water temperature and sali-

nity, and using wind and current modeling (Mungall and Whitaker 1979, Matthews 1978, 1981a, 1981b). Landform characteristics were seen to regulate the inputs and transport behavior (via landform interactions with circulation patterns) of food chain materials. To determine the persistence and stability of these landforms, geologists studied their depositional and erosional histories (Naidu 1979, Cannon and Rawlinson 1979).

An extensive review of research findings on coastal processes in general (see Truett 1981a) provided a background against which to interpret the findings of this program, and to suggest whether the findings of this program could be extrapolated to coastal ecosystems elsewhere.

Results

Some important results of studies are as follows:

1. The barrier island-lagoon system appears to have been formed by intrusion of the sea onto low-lying areas behind topographic highs; the islands themselves are largely reworked remnants of mainland features and do not appear to be nourished extensively by materials transported from elsewhere (Cannon and Rawlinson 1979).

2. Normal patterns of nearshore circulation and estuarine-marine water exchange appear to be mainly wind-generated (Mungall and Whitaker 1979, Matthews 1979,1981b) and parallel those occuring in similar other estuarine systems without strong tidal influence (see Truett 1981b).

3. Anadromous fish in their coastwise migrations concentrate in very shallow waters, principally near the mainland but also in similarly shallow waters near the barrier islands (Craig and Haldorson 1981; Craig and Griffiths 1981).

4. The important fishes and birds eat mainly epibenthic invertebrates (mysids and amphipods) which appear to be available in excess of the energy needs of their predators.

5. The growth rates and consequent secondary production of some of the important epibenthic invertebrates (mysids, amphipods) may be temperature-regulated in the nearshore region (Griffiths and Dillinger 1981).

6. Mysids (and perhaps other epibenthic invertebrates) appear to take advantage of prevailing current regimes to transport themselves within the nearshore region (Griffiths and Dillinger 1981).

7. The food base of most important prey organisms and their predators in the nearshore system is mainly pelagic primary production (Schell 1982).

Discussion and Implications

Prevailing wind regimes in the nearshore region in summer cause rapid water exchange between coastal water bodies, but there are limited rates of exchange between the shallow nearshore and the deeper marine environments (Mungall and Whitaker 1979). Both phenomena are ecologically important. The longshore exchange promotes rapid mixing and great mobility of coastal waters and entrained materials. The nearshore/marine exchanges are probably characterized by a net landward component in the near-bottom currents that promote landward delivery (and subsequent nearshore retention) of materials entrained in the lower part of the water-column (Truett 1981a). Thus available evidence suggests that the nearshore shallows function as a sink for an assortment of entrained materials and organisms transported from the land and from the sea as well as for those arising in situ (i.e. primary production). Implications for development are that contaminants, plankton, and other entrained items would all be highly mobile coastwise, and if they settled, might tend to accumulate in benthic estuarine environments. The mechanisms that make the environment biologically rich might also make it a sink, or trap, for selected pollutants.

Estuaries and other shallow coastal waters of the world are typically highly productive in comparison to the open ocean (Odum 1968, Clark 1977:40, and others) because they (1) accumulate and rapidly recycle nutrients and organic materials, (2) have short, and therefore efficient, food webs, and (3) support rapid growth stages of migrant populations of organisms. Likewise, many arctic ecosystems have simple food webs that support migrant animals during periods of rapid growth; these qualities enhance their secondary production despite the constraints of seasonal cold and darkness (Truett 1981 b).

The study site has qualities typical of other coastal and arctic systems that signal its importance to the vertebrates--oldsquaw, phalaropes, arctic and least ciscoes, arctic char, fourhorn sculpin, and arctic cod. It appears to have moderate levels of primary production (Schell 1982) and as well accumulates food-web materials produced outside the nearshore zone. The fish, birds, and their prey (mysids and amphipods) that assemble there in summer are mostly immigrants.

The fish and birds that consume the mysids and amphipods in summer confine most of their utilization of the nearshore zone to the shallower (<5 m) areas (Johnson and Richardson 1981), especially the lagoons and bays, despite the apparent abundance of their favored foods in the deeper parts of the nearshore waters (Griffiths and Dillinger 1981). This selective utilization of quite shallow nearshore waters is presumably because the habitat features there (shallow depths, presence of emergent land forms, warm waters, etc.) are optimum and that food is sufficiently abundant that nearshore areas without these features need not be utilized. Presumably fish and birds can opt to some extent for other feeding sites within this relatively productive nearshore region should the sites they favor become uninhabitable because of development activities.

The habitat qualities and the biological and physical processes important to fish and birds in the Simpson Lagoon area appear to be shared by other regions along the Alaskan Beaufort Sea coast. Lines of evidence supporting this view include (1) the general documented and theoretical similarities among coastal sites of physical processes (wind and current regimes, sediment transport, etc.) that control the general biological production, and (2) the similarities in biological processes and structural characteristics among coastal sites. Ecosystems similar within themselves

but different from adjacent systems appear to exist within long, narrow bands that follow depth contours along the coast. There is great mobility of the key vertebrate species (Johnson and Richardson 1981, 1982; Craig and Haldorson 1981; Richardson and Johnson 1981; Craig et al. 1982) and probably also of their principal prey within these linear systems. These similarities among coastal sites suggest that (1) extrapolation of many kinds of data among coastal areas for purposes of impact assessment is reasonable and (2) the mobility of components within the coastal ecosystem probably enhances the resilience of the system to localized impacts of development.

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